THE UPPER RICHMOND BEDS OF THE CINCINNATI GROUP.

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Perhaps more geologists, amateur and professional, have been developed upon the Cincinnati arch than in any other region in America. Yet the fact that the beds known as the Saluda have been classed sometimes as occurring beneath the Whitewater beds, and sometimes as above, shows that the Cincinnati stratigraphy is not yet a closed question.

With the hope of determining the exact relationships of the Upper Richmond beds, the field seasons of 1912 and 1913 were spent in studying the upper strata of the northern half of the Cincinnati anticline. The second season's work was made possible by a grant from the Emerson McMillin research fund of the Ohio Academy of Science.

The subdivisions of the Richmond in ascending order have been usually given as Waynesville, or Lower Richmond, Liberty, or Middle Richmond, and Saluda, Whitewater and Elkhorn, constituting the Upper Richmond. We are not concerned here at all with the Waynesville, and but little with the Liberty.

Of these subdivisions, the Saluda beds were the first to be defined*, and were originally termed Madison, from the typical locality at Madison, Ind. But the name being preoccupied, Saluda was substituted.

These Saluda beds at Madison consist of massive, often decidedly arenaceous or argillaceous limestones which have no parallel elsewhere in the northern half of the Cincinnati arch. These heavy strata are of a prevailing grayish color, sometimes bluish or brownish, but weather to various shades of brown. In texture, the rock is smooth-grained and non-crystalline, and except at the top is almost entirely barren of fossils.

The "typical Saluda" of Foerste was given a thickness of 37′, being based at the top of 3′ of sandy limestones just above the top of a conspicuous 2′ reef of the coral Columnaria alveolota. 6′ below the base of this reef is the top of another Columnaria reef, 1′ thick. Cumings includes both reefs in his Saluda† and identifies the lower one with the reef as the base of the Saluda farther north. But, as will be presently shown, it is the upper reef, not the lower, that extends toward the north and north-east. Hence it seems best here to consider the top reef as the base of the Saluda.

*Foerste, Indiana Dept. Geol. & Nat. Resources, 21st Ann. Rept., 1896, p. 220.

†Indiana Dept. Geol. & Nat. Resources, 32nd Ann. Rept., 1907, p. 640.

The Liberty or Strophomena planumbona beds were assigned a thickness of about 35′,* and the base was defined as the first recurrence of Hebertella insculpta. The top was not definitely located, but by general agreement seems to have been taken as the base of a 3′-4′ bed of shales and soft, shaly, blocky limestones, containing Trochoceras baeri, and many characteristic Whitewater clams, and with Pachydictya fenestelliformis just above.

The Whitewater or Homotrypa wortheni beds constituted the remainder of the Richmond, until the distinct and even bedded shales and limestones at the top were separated from the very characteristic soft, lumpy, shaly limestones beneath, and called the Elkhorn.

Beginning with the detailed study of the formation at Madison, the lower Columaria reef is here sometimes underlain by as much as 10′ of the general type of Saluda rocks, only rarely massive and with more shale. These strata contain a few poorly preserved Liberty fossils, Homotrypa wortheni, etc. It may be said here that in Indiana the Trochoceras baeri bed is generally undefined, and no sharp distinction can be made between Liberty and Whitewater. These undefined strata have been named Versailles, from Versailles, Ind.†

The lower reef, like the upper, is quite variable in thickness. Averaging 1′ at Madison, it reaches 3½′ in thickness on a north branch of Razor Creek, five miles north, and then thins out and occurs intermittently at several places northward before disappearing.

Between the reefs at Madison are 6′ of shale. This shale is 4½′ thick along the road following the valley of a westward branch of Crooked Creek, three miles north of Madison. Five miles north of Madison the thickness is only 2′ 4″. In the shale are a few poorly preserved Hebertella sinuata, Platystrophia acutilirata, and Dystactospongia madisonensis.

The second reef thins from 2′ at Madison to 1′ toward Hanover, where it has quite a percentage of Calapoecia cribriformis. At the locality three miles north of Madison it averages only 8″ thick, and five miles north is represented only by a hard, tough, irregular limestone 6″-10″ thick with no distinct colonies. Like the lower reef, the second occurs intermittently as far north as the exposures below the road on the West Branch of Laughery Creek, four miles south of Batesville. Huge isolated colonies, sometimes 4′ across, were seen near Versailles.

Above the second reef are 3′-6′ of shales and thin limestones, in some places carrying a prolific mollusc fauna. Just at Madison this fauna is almost absent, but three miles north were collected Dystactospogenia madisonensis, Dowlsonia cycla, Tetradium

*Nickles, American Geol. Vol. 32, 1903, Pp. 207-9.
†Foerste, Science, N. S., Vol. 22, 1905, P. 150.

minus, Calapoecia cribriformis, Hebertella sinuata, Platystrophia acutilirata, Ischyrodonta truncata, Losphospira bowdeni, Liospira sp., Bellerophon sp., Endoceras sp., Primitia glabra, Isochilina subnodosa, Tetradella simplex, etc., etc.

The Tetradium minus is rather scarce at Madison, but is common 1′ above the second Columnaria reef toward Hanover, and again above the mollusc layers 3 miles north. At the locality five miles north it is very abundant through 7′ of blocky, shaly limestones, immediately above the limestones representing the second reef. From here on this Tetradium horizon is very constant, and occurs whereever the rocks have been exposed as far north as Liberty, Ind. and as far toward the east as Oxford, O.

A mile east of Liberty, where the Oxford pike crosses Hannah's Creek, the Tetradium is scattered abundantly through the whole 4′ 9″ of Saluda rocks. Beneath are exposed 3′ of shales and thin limestones with much the same fauna as is carried by the same strata at Laurel.

North of Liberty only three miles, at the last long exposure on Richland Creek, the Saluda strata have almost lost the Tetradium, and are distinctly shaly except at the top, where they end in two heavy limestones, the lower one 1′ 2″ thick and very irregular, the top one 10″ thick and more even. The top stratum is composed largely of fossil "hash," and in this are water-worn Rhyncotrema capax, etc. It occurs at this level to within four miles of Oxford. Immediately above it are the characteristic Whitewater strata and fauna.

The lower shales are partly replaced by evenbedded limestones along Elkhorn Creek, and at the quarries along the Whitewater River south of Richmond are represented by limestones indistinguishable from those below. But the top stratum is still heavy and characteristic.

While perhaps not strictly the equivalent of the second Columnaria reef, this Tetradium reef developed immediately above it and replaced it further north. Outside the Madison region it bases the Saluda type of strata.

Practically whereever this reef is seen it is closely associated with a fauna similar to the one three miles north of Madison. Sometimes this fauna is above the reef or in it, but usually is beneath. Near Versailles the Dystactospongia is especially abundant and just below it are found, besides the molluscs listed above, Ptilodictya magnificia, Monticulipora epidermata, Leptaena rhomboidalis, Agelacrinus cincinnatiensis, and Lichas sp.

At Oxford, Ohio, the first incursion of the Whitewater fauna is preserved in the 3′ of Trochoceras shales, and among the clams are such characteristic forms as Byssonychia grandis, B. richmondensis, Ischyrodonta elongata, I. truncata Opisthoptera casei, Ortonella hainesi, and Whitella obliquata.

Between the top of this bed and the base of the Tetradium reef are about twenty feet of more or less even bedded limestones and shales, so we thus see that there are, here at least, as much as twenty-three feet of Whitewater strata *beneath* the base of the Saluda. Even should we base the Saluda with the lower Columnaria reef at Madison, the result would be but little change, and nowhere could the Saluda be said to be beneath the Whitewater.

Above the Tetradium level at Madison are 37′-40′ of massive, typical Saluda strata, almost wholly barren of fossils except near the top. As one goes north the strata immediately above the basal reef becomes more fossiliferous, the best localities for collecting being near Hamburg, Ind., and Oxford, O., at the latter place being 3′ thick. The fauna is characterized by the scarcity of Brachiopoda and Bryozoa, and includes Leperditia appressa, L. cylindrica, L. caecigena, Ceratopsis chamersi, Eurychilina striatomarginata, Primitia glabra and Tetradella simplex, the first four of these ostracods being recurrent Trenton species. Other fossils are Byssonychia grandis, B. richmondensis, several species each of Cyrtoceras and Orthoceras, Tryblidium indianense, etc., etc. Fragments of a large Euryteroid are found, and remains of plants are occasionally found.

Everything in these strata points to a shallowness of the sea, and a nearness to land, and it is hoped that there will be found in these rocks some definite information as to the nature of the land life of the closing Ordovician.

Above the Saluda type limestones in the Oxford region are about 10′ of thin limestones and shales, sometimes just crowded full of Bryozoa, mostly several species of Homotrypa, including H. wortheni. It is the Bryozoa from these beds that have given the name Coral Banks to the dump from the R. R. cut above Oxford.

West of Cross Plains about one and a half miles, nine miles south of Versailles, a second Tetradium horizon appears, only this "reef" has in places as much Labechia as Tetradium. At Cooper's Falls, four miles south of Versailles, it occurs in the breast of the first little fall below the road, is only 1′ thick, and is about 30′ above the top of the lower reef.

This horizon was not seen at Versailles, but doubtless closer examination would show it. It occurs, however, at all other localities as far north as Laurel and as far eastward as a number of exposures on little tributaries of Indian Creek, three miles west of Oxford, O. In this latter region the Labechia is absent, and the Tetradium forms a definite, hard, massive reef, in places two and one-half feet thick. Most of the colonies are upside down, giving evidence of wave action upon this ancient reef, much as upon the reefs in the present coral seas.

Sometimes 2′-3′ below this second Tetradium reef is another 1′ of Tetradium. Between these Indian Creek exposures and Oxford this reef disappears and is not known to the east.

And between the two reefs at this locality are not only the 10′ of Bryozoa beds, but about 20′ of characteristic soft, lumpy, shaly Whitewater strata with the characteristic Whitewater fauna. The Rhynchotrema dentata beds appear just above the reef. Hence we see from the position of these two reefs that the Saluda is in part the equivalent of the Whitewater.

Returning to the Madison section to pick up another marker and trace it through, we find that the extreme top of the Richmond is again fossiliferous. Just above the Hanging Rock these fossiliferous strata begin with 8″ of thin limestones and dark shale, with Byssonychia richmondensis, Pterinea demissa, Orthoceras hammelli, Labechia ohioensis, and Tetradium minus. Next is a 16″ massive dark limestone, with a richly fossiliferous film of rather poorly preserved fossils on the top. These fossils constitute a distinct and peculiar fauna, part of which appears to have no near relationship in the Cincinnati. The more common species are Labechia montifera, Labechia sp., Streptelasma sp., Ctenodonta sp., Pterinea demissa, Liospira sp., Holopea hubbardi, Lophospira hammelli, Orthoceras hitzi, O. gorbeyi, and Cyrtocerina madisonensis. At the exposures along the road to Hanover, three miles west of Madison, there are added Hebertella sinuata, Platystrophia acutilirata, Leperditia caecigena, Labechia ohioensis and Tetradium minus, there being no distinction here between the two fossil layers as at Madison. This assemblage of fossils constitutes the so-called "Hitz fauna."

Between the Hitz fauna proper at Madison and the Ordovician-Silurian contact, is a 2′ 4″ limestone with all of the ostracods listed from the Saluda of Oxford, except Leperditia appressa, and with Entomis madisonensis added. This ostracod limestone is not distinct at the locality three miles west.

Between Madison and Cooper's Falls the Tetradium and Labechia become consolidated into a rather definite reef, though not of great thickness. At Cooper's Falls this reef is 1½′ thick. It is about 19′ above the second Tetradium reef and 5′ beneath the Silurian contact. These 5′ are massive limestones much like the top limestones at Madison, and carry a reduced Hitz fauna. The Hitz fauna is seen no farther toward the north.

This third reef is seen constantly at about this level, whereever it is exposed, around the northern edge of the Cincinnati outcrops as far east as the vicinity of Waynesville, O. The only place where it was not seen was at Laurel, and a more careful examination of the strata would doubtless show it here.

On Elkhorn Creek the total thickness of the beds between the level of the lower reef and the Silurian contact is about 125′, as

contrasted with 71′ at Laurel and 57′ at Cooper's Falls. The presence on Elkhorn Creek of the upper reef, 8′ 4″ below that Silurian contact, shows that this thickening of strata is due to the more rapid accumulation of sediments toward the north. In the region about Camden, O., which is as far eastward as the Saluda can be traced, the thickness of strata between the level of the lower reef and the upper reef is about 100′, as nearly as the various exposures can be correlated.

It is not the usual thing to have limestones and calcareous shales accumulating more rapidly than the more shallow water sands and shales, but between the limits of the lower and upper reefs on Elkhorn Creek the calcareous sediments accumulated over three times as fast as the argillaceous and arenaceous sediments to the north. The land evidently was so low as to suffer from little erosion, and the sea about it so shallow that the shifting sands and muds were kept stirred up by the waves when not exposed between tides, as shown by the ripple marks and sun cracks at various levels. Thus the organic accumulations here would be reduced to a minimum while to the north the usual favorable conditions would prevail.

Of these 125′ of strata on Elkhorn Creek, about 75′ at the base are typical Whitewater sediments with the typical fauna. The remaining strata are 15′ of barren shale at the base, with predominating shales and more or less even-bedded limestones to the Silurian contact. These strata constitute the Elkhorn beds, and bear a fauna quite distinct from the Whitewater.

The change from the Saluda sediments and fauna begins at Cooper's Falls. Beneath the upper reef there are 7′ of heavy Saluda limestones, and beneath those about 10′ of thin, somewhat lumpy, barren shales and limestones.

At Versailles the second reef was not seen and the sections studied did not run high enough to show the upper reef. But the 10′ of strata at Cooper's Falls are represented at the top of the Versailles section by 9′ of strata which are much softer and more lumpy than at Cooper's Falls, and they bear quite a fauna of a Composite Whitewater—Elkhorn type.

Three miles north of Osgood, on Big Plum Creek and in that vicinity, these strata are thicker, more characteristically Whitewater at the base, then with even bedded shales and limestones up to the upper reef, which is 2′ thick and 5′ beneath the Silurian.

On a north fork of Big Salt Creek, west of Oldenburg, the Richmond ends with 40′ of apparently fossiliferous strata. (The middle of this 40′ is covered.) At the base are about 10′ of strata with Rhynchotrema dentata, Strophomena sulcata, S. vetusta, Platystrophia laticosta, P. acutilirata, Monticulipora epidermata, Batostoma varians, Rhombotrypa quadrata Byssonychia richmondensis, Ischyrodonta truncata, Conularia sp., Cornulites sp.,

Protarea vetusta, Streptelasma rusticum, S. divaricans, etc. etc. At the top are Schizolopha moorei, Salpingostoma richmondensis, Platystrophia lynx, the species of Platystrophia, Strophomena, and Streptelasma listed above, Rhynchotrema capax, Protarea vetusta, etc. etc.

On Big Sains Creek near Laurel the 55′ of strata between the second reef and the Silurian are largely barren. No good exposures at this level are seen between Laurel and Elkhorn Creek. But between these places the fossils become differentiated into the distinct Whitewater and Elkhorn faunas.

Nowhere on the upper half of the Cincinnati arch was more than a local unconformity seen between the Richmond and the Silurian. Usually it was quite difficult to tell just where Ordovician ended and Silurian began.

The upper reef varies in position from immediately beneath the contact three miles west of Madison, to an extreme of 14′ beneath it near Waynesville. In this latter region a conspicuous band of purple shale appears about 5′ above the reef and occurs constantly at about this level everywhere on the east side of the arch.

To summarize in conclusion, all of the Elkhorn and nearly all of the Whitewater are but the deeper water equivalents of the shoal water Saluda to the south.

Second: The only Saluda in Ohio is in the northern part of Butler and southern part of Preble Counties.

Third: The third coral reef and the purple shale together show that the top of the Ordovician is quite uniform and that any unconformity is but slight, and close examination of the contact bears this out.

Oxford, Ohio.